HAYATI
Journal of Biosciences
ISSN: 1978-3019
EISSN: 2086-4094

Biological Conservation of Molluscs Based on Spatial and Temporal Distribution in Tropical Tidal Lake, Medan-Indonesia

Fredinan Yulianda[1*], Ahmad Muhtadi[2,3], Mennofatria Boer[1], Majariana Krisanti[1], Yusli Wardiatno[1]

[1]*Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, Bogor, Indonesia*
[2]*Doctoral Program in Aquatic Resources Management, Graduate School of IPB University, Bogor, Indonesia*
[3]*Department of Aquatic Resources Management, Faculty of Agriculture, Universitas Sumatera Utara, Medan, Indonesia*

ARTICLE INFO

Article history:
Received June 24, 2019
Received in revised form August 30, 2020
Accepted September 5, 2020

KEYWORDS:
Polymedosa expansa,
biodiversity,
coastal lake,
mussel,
snail

ABSTRACT

The tidal lake ecosystem is formed by the flow of the Belmera River and seawater through a tidal process along a course of 12 km from Belawan (Malacca Strait). This lake has a tidal lake that has the characteristics of fresh water to brackish water and Mollusc communities from freshwater species to brackish water species. This study was performed to develop a mollusc conservation strategy based on the spatial and temporal distribution of Mollusca in the tides. The study was conducted from September 2018-August 2019. Mollusc samples were taken every month at high tide and low tide using a Petersen grab tool. Nine Mollusca species, consisting of three bivalves and six gastropods, were identified. *Polymedosa expansa* is a mollusc species that is considered for conservation. The population size of *P. expansa* is small, and its distribution is limited to the northern lake. *P. expansa* was found only in September at high tide and in December at low tide. Competition among Mollusca and habitat availability are obstacles to the survival of *P. expansa*. The habitat of *P. expansa* is mangrove, and therefore a conservation approach was carried out through improvement of mangrove quality.

1. Introduction

Lake Siombak is a tropical tidal lake in Indonesia (Muhtadi *et al.* 2020a). This lake located on the north coast of Medan City, North Sumatra Province is unique because the Belmera River flows into the lake along a course of 12 km from Belawan (Malacca Strait). Moreover, the lake is still affected by tides. The tides affect the difference in daily water level elevation and month periods (Muhtadi *et al.* 2017; Muhtadi *et al.* 2020a). Muhtadi *et al.* (2020a) reported that the water level elevation ranges from −0.43 to 2.66 m during rains and −0.04 to 2.23 m during the dry season. This difference in elevation results in differences in lake depth, including other morphometric parameters and lake water quality.

The existence of tidal dynamics will also affect the allocation and distribution of lake water organisms, thus affecting the dynamics of tidal lake communities (Reis-Filho *et al.* 2011; Muhtadi *et al.* 2016; Pérez-Ruzafa *et al.* 2019). Therefore, aquatic organisms, both flora and fauna that inhabit the tides, have become unique and distinctive. The uniqueness of this tidal lake ecosystem can be seen by the presence of flora in the form of mangroves growing on the edge of the lake (Leidonald *et al.* 2019; Muhtadi *et al.* 2020b), including various fresh, brackish and marine ichthyofauna communities (Muhtadi *et al.* 2016; Leidonald *et al.* 2019).

Other organisms found in tidal lakes include macrozoobenthos from mollusc phyla (Muhtadi *et al.* 2016). Molluscs are soft animals with a shell, which can be found both on the surface (epifauna) and within the substrate (infauna) (Dharma 2005; Suwignyo *et al.* 2005). They can also be attached to macrophytes, including mangroves (Suwignyo *et al.* 2005). Most molluscs that live in water are from the classes of gastropods and bivalves (Carpenter and Niem 1998). In general, molluscs play a role in the food chain as detritivores. Molluscs at the trophic level are classified into detritivores, herbivores and carnivores (Suwignyo *et al.* 2005). Molluscs are benthos animals that have high adaptability to various habitats, including accumulating heavy metals, and thus can be used as environmental indicators (Kuk-Dzul *et al.* 2012; Dabwan and Taufiq 2016; Grenz *et al.* 2017). Molluscs are used economically as industrial materials, jewellery, cosmetics, pharmaceuticals, animal feed and fertiliser (Suwignyo *et al.* 2005;

* Corresponding Author
E-mail Address: fredinan@apps.ipb.ac.id

Purwaningsih 2012; Chelladurai and Moorthy 2019; Khan and Liu 2019). Some gastropods have high nutritional value for consumption (Lah *et al.* 2017; Rasyid and Dody 2018).

Tidal lakes have a unique ecological system, especially mollusc communities and habitats consisting of two types of communities; i.e., freshwater communities and brackish communities. The ecological system of Lake Siombak is still dominated by freshwater systems, although some brackish communities have important habitats at certain times. Based on its uniqueness, the *Polymedosa expansa* shell community, which is a brackish water species and occupies a specific habitat, may require protection. This study was performed to examine the ecological system of molluscs, specifically to determine conservation strategies aimed at the development and distribution of *P. expansa* populations in Lake Siombak.

2. Materials and Methods

2.1. Study Area

Sampling of Mollusca was carried out at 11 locations in the tidal lake ecosystem in Medan City, North Sumatra Province: eight locations within the lake and three outside the lake (Figure 1). Data were collected monthly for 1 year from September 2018-August 2019.

2.2. Procedures of Sampling

Mollusca sampling was carried out three times during high and low tides using Petersen grab with a mouth width opening 30 x 30 cm. Mollusca samples were sorted from mud and rubbish and then preserved in 10% formalin solution. Identification was carried out at the Integrated Resource Management Laboratory, Faculty of Agriculture, University of North Sumatra with reference to Dharma (2005), Carpenter and Niem (1998), and Hamli *et al.* (2012).

2.3. Data Analysis

Data analysis was performed in conjunction with the Mollusca community structure on tidal lake through several attributes such as the Shannon-Wiener diversity index (H'), evenness (E) and dominance (D) (Odum and Barret 2005; Krebs 2014). Mollusca diversity was calculated using the diversity index of Shannon-Wiener (Shannon and Wiever 1964) with the following formula:

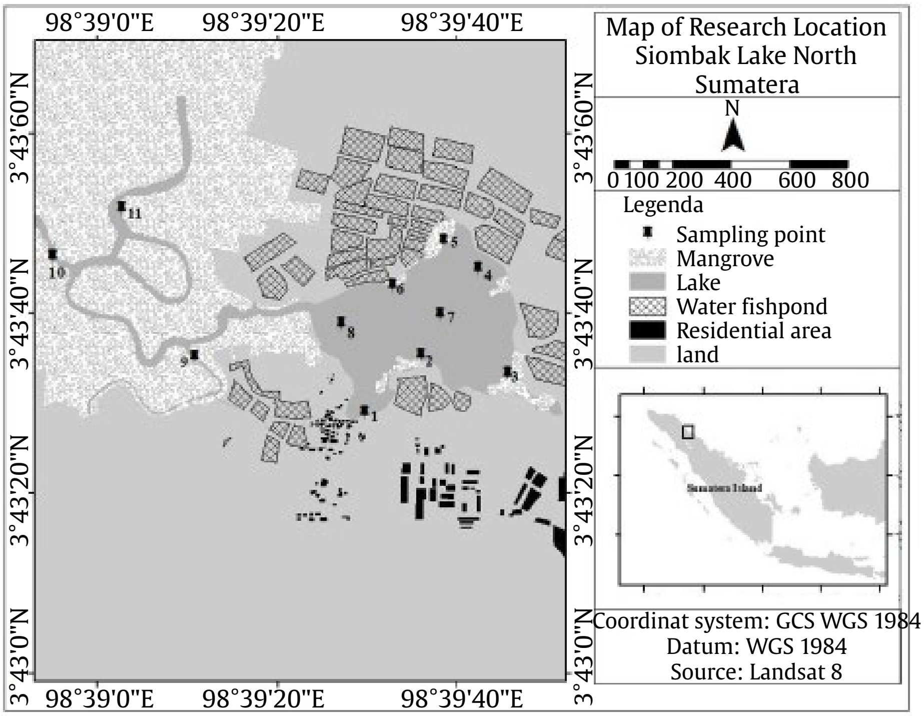


Figure 1. Location of tropical tidal lake

$$H' = -(\sum pi \log_2 pi)$$

Explanation:
H' = species diversity index,
ni = number of individuals of each species,
N = number of all individuals
Pi = important Probability for each species = ni/N,

The equitability index (E) was calculated by following the equation (Krebs 2014):

$$E = H'/H`max$$

Explanation:
E = Shannon-Wienner uniformity index,
H = species balance,
H`max = maximum diversity index ($\log_2 S$),
S = total number of species

The dominance index is calculated according to the Simpson index in Odum and Barret (2005).

$$C = \sum (ni/N)^2$$

Explanation:
C = index of dominance,
ni = number of individuals of each species,
N = total individual community

3. Results

3.1. Richness and Composition of Molluscs

Ten species of molluscs from seven families were found during the observations at Lake Siombak. The molluscs consisted of three bivalves and seven gastropods (Table 1 and Figure 2). The species found in Lake Siombak are a group of molluscs living in estuaries or at sea, with the exception of *Pomacea canaliculata*, which is a freshwater species. The richness of molluscs discovered previously (in 2014) is slightly lower, at seven species. This is related to the length of the research period and number of sampling sites.

3.2. Spatial Distribution

The greatest number of molluscs at low tide was seen at station 5, where they reached 15,785 individuals (ind)/m², and at high tide the greatest number of molluscs was seen at station 8, where they reached 11,867 ind/m². Meanwhile, the lowest numbers of molluscs were seen at station 7 at both high (504 ind/m²) and low tide (463 ind/m²) (Figure 2 and Tables 2 and 3). *P. expansa*, an economically valuable species consumed by humans, was found in

Table 1. Richness of Molluscs at tidal lake

Spesies	Family	Indonesian name	Local name	Common name
Arcuatula arcuatula	Mytilidae	Kerang	Korang	Arcuate mussel
Arcuatula senhousia		Kerang batik		Senhouse horse mussel
Cerithidea obtusa	Potamididae			Mud Creeper snail
Cerithideopsilla alata				Mud snail
Nerita balteata	Neritidae		Keong merah	Violet nerite
Nerita ocellata			Keong merah	Violet nerite
Nerita violacea			Keong merah	violet moon snail
Polymesoda expansa	Corbioculidae	Kerang totok	Lokan	mangrove clam
Pomacea canaliculata	Ampullariidae	Keong mas	Keong mas	golden apple snail
Sphaerassiminea miniata	Assimineidae		Keong	red berry snail

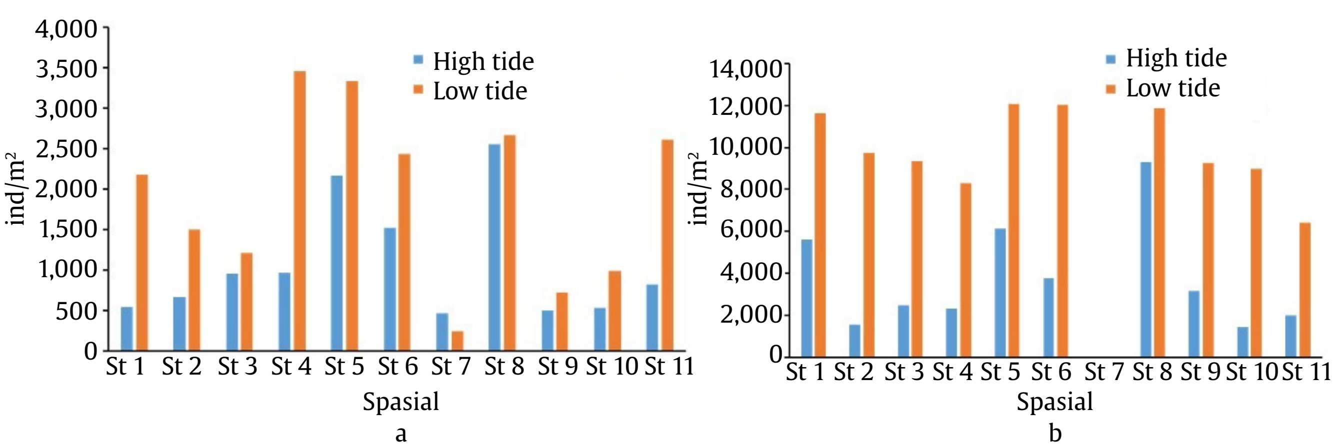


Figure 2. Spatial distribution of Mollusc density during rainy (a) and dry season (b)

September at high tide and in December at low tide in the northeast part of the lake (Tables 2 and 3). The abundance and distribution of *P. expansa* populations are minimal compared to other of molluscs. Molluscs species rivalry and habitat availability are constraints for the survival of *P. expansa* although the presence of mangroves as *P. expansa* habitat is widespread in the lake and river mouth.

3.3. Temporal Distribution

Temporally, molluscs showed the highest abundance during the dry season (February–July) compared to the wet season (August–January) at both high and low tides (Figure 3 and Tables 4 and 5). The abundance of molluscs during the dry season reached 1,744–40,948 ind/m^2 at low tide and 1,500–10,237 ind/m^2 at high tide. In the wet season, the abundance of molluscs did not exceed 5,000 ind/m^2 at high or low tide. The peak of the mollusc population at Lake Siombak was seen in June, while the lowest was seen in October. *A. arcuatula* was abundant and easily found each month. Carpenter and Niem (1998) reported that this species is a bivalve with a preference for soft substrates (clays) that lives in groups. However, there has been little specific research related to *A. arcuatula* populations.

4. Discussion

4.1. Species Richness and Diversity Index

The results of this study showed that there were more gastropods (six species) than bivalves (three species) in this location, consistent with previous research indicating that gastropod species are more numerous than bivalves, specifically in lake and estuary areas (including mangroves) (Hartoni and

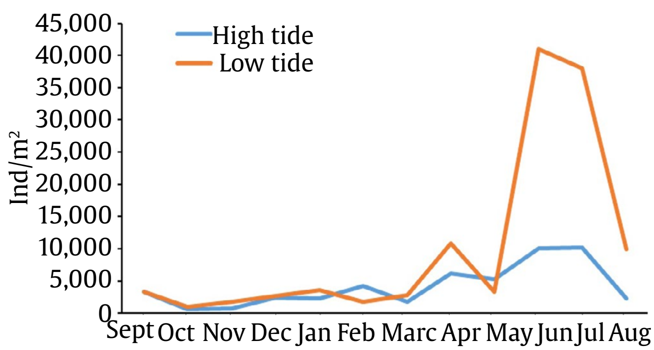


Figure 3. Mollusc temporal distribution at tidal lake

Table 2. Mollusc density during low tides based on the spatial at tidal lake

Species	Station (ind/m^2)										
	St 1	St 2	St 3	St 4	St 5	St 6	St 7	St 8	St 9	St 10	St 11
A. arcuatula	13,433	11,207	10,778	11,581	15,170	14,493	200	10,963	9,659	10,004	8,141
C. obtusa	148	44	122	48	67	67	-	281	107	41	30
C. alata	296	104	293	78	537	115	304	756	226	148	111
M. senhousia	-	-	-	-	-	-	-	-	-	-	-
N. balteata	-	-	-	-	-	-	-	-	-	-	-
N. ocellata	-	-	-	4	-	-	-	4	-	-	-
N. violacea	48	11	7	11	-	-	-	63	22	-	11
P. expansa	-	-	-	-	4	-	-	-	-	-	-
P. canaliculata	11	7	26	-	7	15	-	11	4	7	37
S. miniata	-	-	4	-	-	4	-	4	-	-	-
Total	13,937	11,374	11,230	11,722	15,785	14,693	504	12,081	10,019	10,200	8,330

Table 3. Mollusc density during high tides based on the spatial at tidal lake

Species	Station (ind/m^2)										
	St 1	St 2	St 3	St 4	St 5	St 6	St 7	St 8	St 9	St 10	St 11
A. arcuatula	5,989	2,070	3,170	3,126	8,196	5,137	289	11,374	3,385	1,859	2,522
C. obtusa	59	15	11	30	19	48	-	159	133	11	52
C. alata	100	107	219	130	81	93	167	263	44	85	181
M. senhousia	-	-	56	-	-	-	-	-	-	-	-
N. balteata	-	4	-	-	-	-	-	-	-	-	-
N. ocellata	-	-	-	-	-	-	-	-	22	-	11
N. violacea	-	22	-	-	19	4	-	15	70	4	52
P. expansa	-	-	-	-	-	-	-	-	-	4	-
P. canaliculata	-	4	4	4	7	-	-	15	4	4	7
S. miniata	-	11	-	4	-	11	-	14	-	-	4
Total	13,937	2,233	3,459	3,293	8,315	5,293	463	11,867	3,659	1,967	2,830

Table 4. Mollusc density during low tides based on the month at Lake Siombak

Species	Month (ind/m^2)											
	Sept	Oct	Nov	Dec	Jan	Feb	Marc	Apr	May	Jun	Jul	Aug
A. arcuatula	2,793	756	1,474	1,644	2,448	1,693	1,919	10,752	3,256	39,541	37,374	9,870
C. obtusa	-	-	-	7	11	-	22	22	63	456	315	56
C. alata	567	196	189	22	96	7	44	-	56	948	274	48
M. senhousia	-	-	-	-	-	-	-	-	-	-	-	-
N. balteata	-	-	-	-	-	-	-	-	-	-	-	-
N. ocellata	-	-	-	-	-	-	-	-	-	-	-	7
N. violacea	-	4	59	-	19	44	-	-	-	4	4	11
P. expansa	-	-	-	4	-	-	-	-	-	-	-	-
P. canaliculata	-	-	-	-	-	-	-	-	-	-	-	-
S. miniata	-	-	-	-	-	-	-	-	-	-	-	-
Total	3,359	956	1,722	1,678	2,574	1,744	1,985	10,774	3,374	40,948	37,967	9,993

Table 5. Mollusc density during high tides based on the month at Lake Siombak

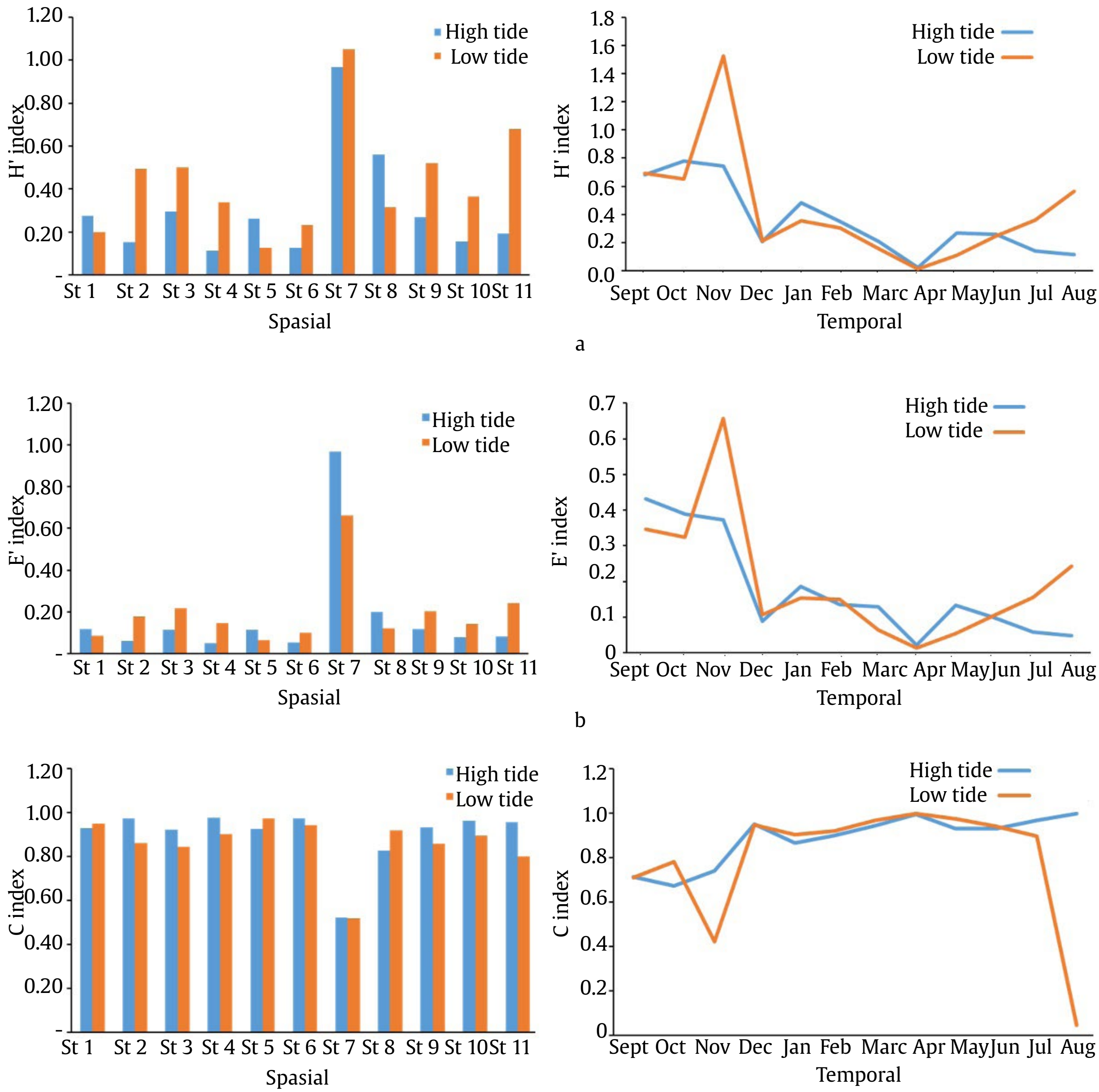
Species	Month (ind/m^2)											
	Sept	Oct	Nov	Dec	Jan	Feb	Marc	Apr	May	Jun	Jul	Aug
A. arcuatula	2,733	307	430	2,000	2,185	3,137	1,478	6,185	5,252	9,800	9,696	2,126
C. obtusa	-	-	52	-	-	-	11	-	22	78	326	33
C. alata	567	44	244	30	4	115	7	-	37	167	200	37
M. senhousia	-	-	-	-	56	-	-	-	-	-	-	-
N. balteata	-	-	-	-	-	-	-	-	-	-	-	4
N. ocellata	-	-	-	-	-	-	-	-	-	-	-	33
N. violacea	-	-	30	7	7	-	4	7	4	52	15	-
P. expansa	4	-	-	-	-	-	-	-	-	-	-	-
P. canaliculata	-	-	-	-	-	-	-	-	-	-	-	-
S. miniata	-	-	-	-	-	-	-	-	-	-	-	-
Total	3,304	352	756	2,037	2,252	3,252	1,500	6,193	5,315	10,096	10,237	2,233

Agussalim 2013; Muhtadi *et al.* 2016; Baderan *et al.* 2019). Gastropods found in the waters play an essential role in the structure of the food chain; i.e., in the process of litter decomposition and mineralisation of organic material, especially those that are detritivores (Suwignyo *et al.* 2005). That is, the gastropods chop leaves into small parts, and the decomposition process is then continued by microorganisms (Santoso *et al.* 2016). Meanwhile, bivalves are generally given more water as filter feeders, more as infauna or epifauna.

Based on several studies of tidal and estuarine lakes, the richness of molluscs at Lake Siombak is high. Rimadiyani *et al.* (2019) found only three species in Western Segara Anakan Lagoon (Central Java), and there are only two mollusc species in Terminos Lagoon (Mexico) (Grenz *et al.* 2017). However, the biodiversity richness in this tidal lake is still lower compared than that in the coastal lagoon Celestum (Peninsula), comprising 14 species (Kuk-Dzul *et al.* 2012), and Nallavadu lagoon (India), comprising 15 species (Padmavathy and Anbarashan 2013). This number is still fewer than that in the Belawan estuary (tidal lake estuary), in which 14 species were found (Fitrianti 2014).

The diversity index (H′) of molluscs in tidal lakes is low (<1) (Figure 4). Spatially, the highest diversity was found at station 7 at both high and low tide, although the type richness at this station was only two species. Therefore, species richness did not necessarily indicate a high H′. This was related to the uniform and non-dominant proportions of each species at station 7. As can be seen in the high uniformity value of station 7, the dominance value was also low at this station. H′ was also not consistent with the population number (abundance) of molluscs, the populations of which were high at stations 5 and 8 but the H′ values were lower than at the other stations. Therefore, H′ is not only influenced by species richness, but also by the proportion of each species in the community.

Temporally, the H′ was also low (<1) (Figure 4). The H′ of molluscs was high in the rainy season and low in the dry season. This was different from the abundance of molluscs, which was higher in the dry season than the rainy season. These observations indicated that the high population of molluscs in the dry season is



c

Figure 4. Spatial and seasonal variability of species richness (a), species diversity (b), abundance (c), and evenness (d) in Siombak Lake

only dominated by certain species; i.e., *A. arcuatula*. Therefore, *A. arcuatula* dominated tidal lake waters both spatially and temporally.

4.2. Spatial and Temporal Distribution

The low molluscs at this location is caused by microhabitat conditions that are less suitable for mollusk. This is caused by deeper water conditions (>10 m) where the salinity found at the bottom of the lake is higher than the surface (Figure 5). Dry season at depths above 9 m can reach 20 ppt (Figure 5) so that no molluscs are found in station 7. Rainy season at the bottom of the lake salinity conditions of about 10 are still found in a few molluscs at that point. Furthermore, Hummel *et al.* (2016) and Morelos-Villegas *et al.* (2018) reported that the distribution of

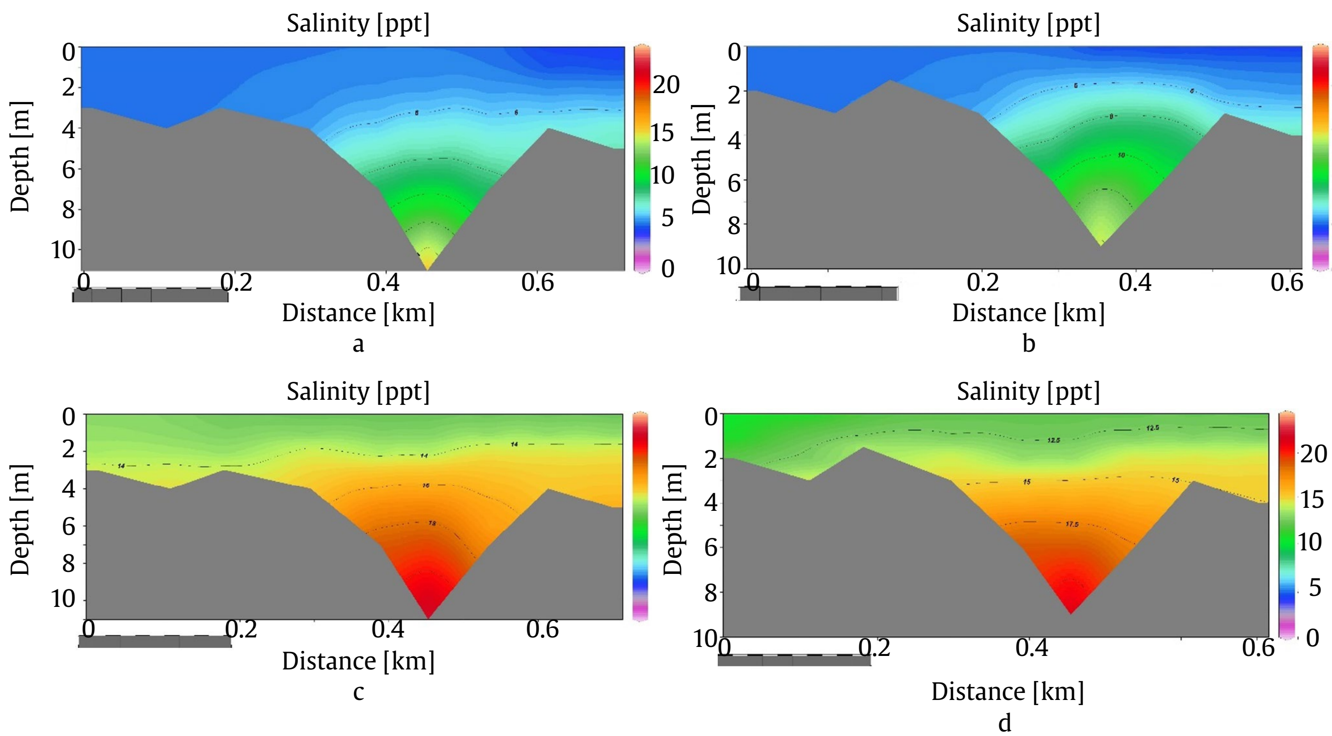


Figure 5. Vertical distributions of salinity at Siombak lake. (a) high tide wet season, (b) low tide wet season, (c) high tide dry season, and (d) low tide dry season (Sources: Muhtadi *et al.* 2020a)

salinity is one of the constraints on the distribution of molluscs in estuaries. Low molluscs at station 7 is also caused by anoxic conditions. Odum and Barret (2005) said that oxygen is a limiting factor in lake waters, where in anoxic bottom waters rarely found organisms, except anaerobic bacteria. This is due to the existence of differences in molluscs in lakes and differences in the effect of salinity.

The spatial distribution of molluscs in the tidal lake ecosystem shows different patterns at high and low tide. Mollusc populations at high tide were denser than in the estuary area in the lake and east of the northern part of the lake, and lower toward the river (west) and east of the southern end of the lake. Mollusc populations at low tide were larger than at high tide, and were concentrated throughout the lakeside and slightly toward the river (Figure 6). These observations showed that the microhabitat of lake water (inundated) is more suitable for molluscs than those of the rivers. Currents in rivers and estuaries can be limiting factors for the distribution of mollusc abundance (Odum and Barret 2005; Hummel *et al.* 2016; Morelos-Villegas *et al.* 2018). Molluscs were more abundant in the north supported by mangrove habitat. Moreover, the north also has a sandy clay substrate that is suitable for mollusc communities, including *P. expansa* (Riniatsih and Kushartono 2009; Hummel *et al.* 2016).

The Mytilidae family (by species *A. arcuatula*) is widespread in the tidal lake ecosystem. Mytilidae is a class of sea-dwelling bivalves (estuary), with only one freshwater group. Thus, in the tidal lake during the dry season, the population of Mytilidae is very high because of the higher salinity of the water (>10 ppt). In addition to Mytilidae, Cerithidae is a native mangrove gastropod (estuary) that is frequent and abundant in the mangrove ecosystem (estuary) (Budiman 1991). Cerithidae molluscs were found throughout the year (Tables 4 and 5) due to the characteristics of Lake Siombak waters, which are influenced by tides from the Belawan Sea (Malacca Strait)) (Muhtadi *et al.* 2017), and strong currents from tides can affect the distribution and movement of molluscs in the water (Hummel *et al.* 2016).

The tidal movement also determines the distribution of mollusc communities, and in general, the abundance and diversity of molluscs are higher at low tide than that at high tide (see Tables 2–5 and Figures 5 and 6). Low tide causes water to become shallower so that oxygen reaches the bottom more at low tide than at high tide. *A. arcuatula* has a wide distribution and has high competitiveness, but *P. expansa* has a limited distribution both spatially and temporally (Figure 7). Competition with *A. arcuatula* and environmental pressures resulting in limited density and distribution

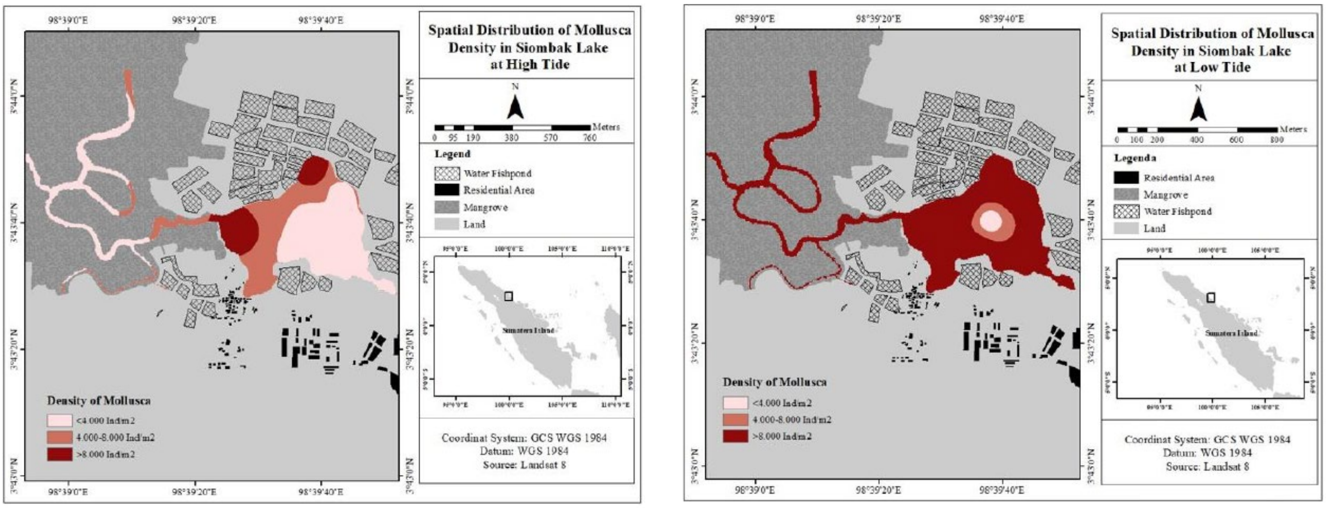
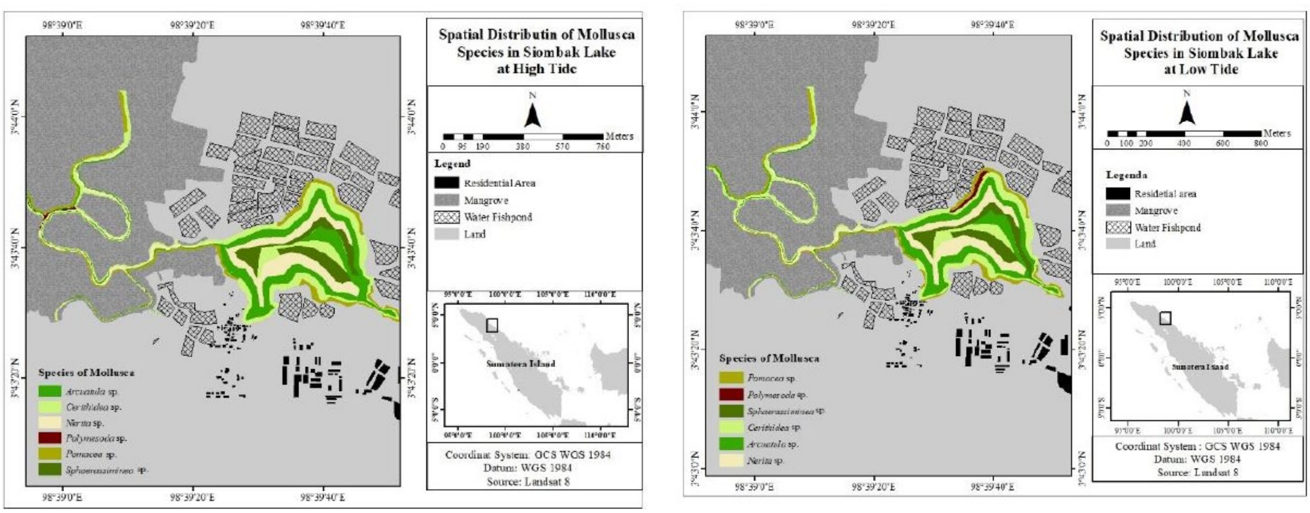


Figure 6. The map of molluscs density at the tide lake during high (a) and low (b) tides



a b

Figure 7. Spatial distribution of Mollusc species at high (a) and low tides (b)

of *P. expansa* in Lake Siombak. Riniatsih and Kushartono (2009) reported that the substrate and particle type are environmental factors that affect the frequency of competition for the distribution of macrozoobenthos, such as molluscs, because each genus has a different way of life or has adapted to the type of substrate in its habitat. This is a matter of concern for management because *P. expansa* species are of economic value and are consumed by humans.

4.3. Conservation Strategy for *P. expansa*

P. expansa, one member of the mollusc community in Lake Siombak, has important economic value as a food source. The *P. expansa* conservation strategy must take into consideration the limited population abundance, as well as the narrow habitat distribution. *P. expansa* populations require habitats characterised by brackish salinity and the presence of mangroves with muddy dense substrates. These habitat characteristics are found in several locations at the tidal lake. Conservation is intended to have a spill over function as a brood stock source that can contribute to breed in other areas so that *P. expansa* becomes more widespread and more sustainable in the tidal lake. The conservation management strategy uses a zoning system consisting of core zones and utilisation zones (Figure 8). The core zone is an area that cannot be exploited but functions as a source of germ plasma while the utilisation zone, which will later function as a seashell harvesting area, requires the formation of *P. expansa* shellfish populations. Rehabilitation of shellfish populations is carried out in selected habitats in the utilisation zone

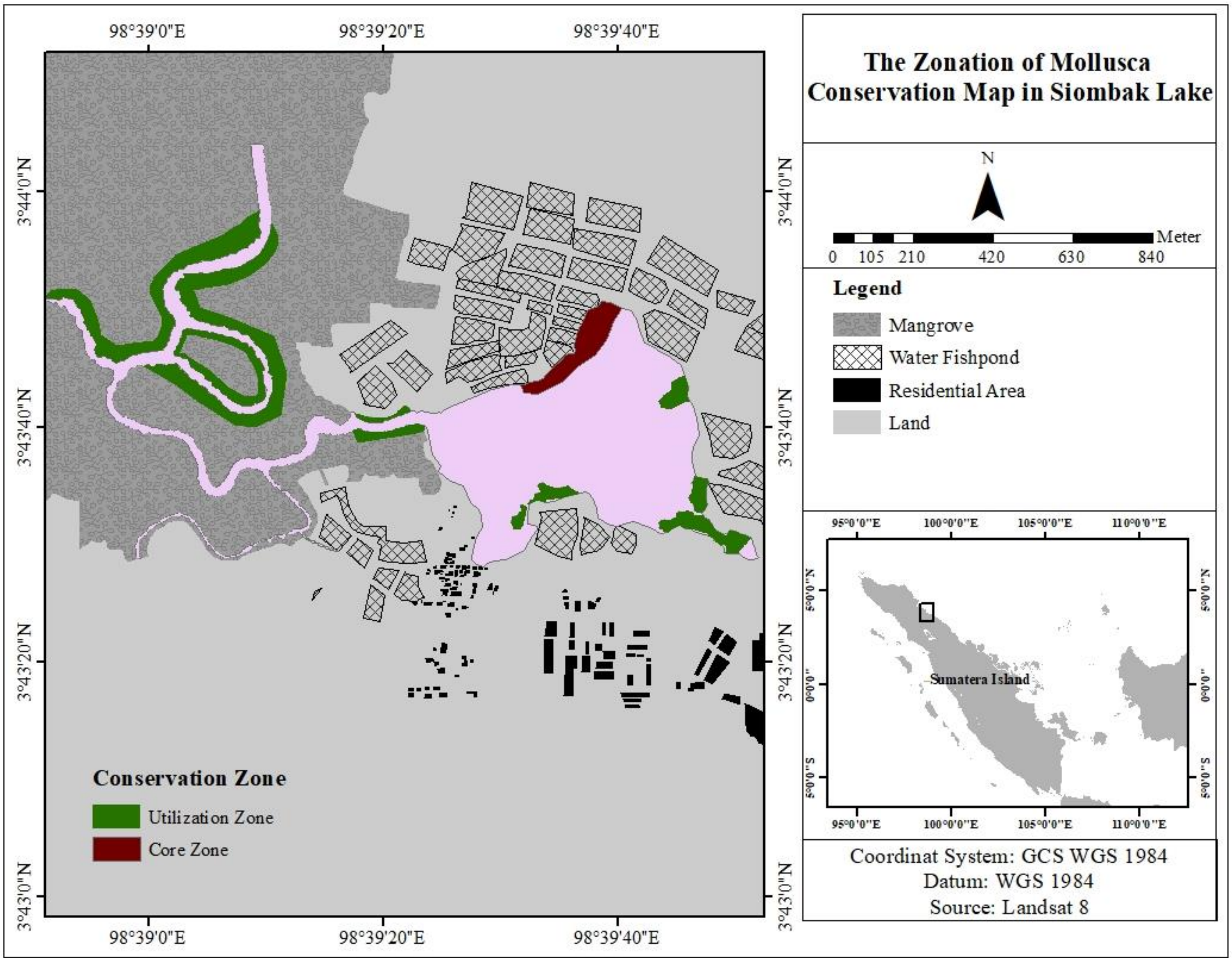


Figure 8. Conservation strategy of *Polymedosa expansa* at tidal lake

through habitat expansion by spreading of *P. expansa* populations originating from the core zone.

Acknowledgements

This research was funded by Directorate of Research and Community Service, Ministry of Research, Technology, and Higher Education through doctoral dissertation research schemes with Letter of Agreement/Contract Number 3/E1/KP.PTNBH/2019. Thanks to the team of Lake Siombak–Students of University of Sumatera Utara for the assistant given in the field and laboratory.

References

Baderan DWK *et al.* 2019. The abundance and diversity of Mollusks in mangrove ecosystem at coastal area of North Sulawesi, Indonesia. *Biodiversitas* 20:987-993.

Budiman A. 1991. Penelaahan beberapa Gatra Ekologi Moluska Bakau Indonesia [Disertasi]. Depok, Indonesia:Universitas Indonesia.

Dabwan AHA, Taufiq M. 2016. Bivalves as bioindicators for heavy metals detection in Kuala Kemaman, Terengganu, Malaysia. *Indian J Sci Technol* 9:1-6.

Dharma B. 2005. *Recent dan Fossil Indonesian Shell*. Germany. Conchbooks.

Carpenter KE, Niem VH. 1998. FAO Species Identification Guidie for Fishery Purposes. The Living Marine Resources of the Wastern Central Pacific Volume 1. Food and Agriculture Organization of the United Nations. Rome

Chelladurai G, Moorthy G. 2019. Biochemical composition of some commercially important marine gastropods from Tuticorin Coast, South East Coast of India. *EC Nutrition* 14:26-42.

Fitrianti. 2014. The diversity and distribution of bivalva in aquatic estuary Belawan in North Sumatera [Thesis]. Medan, Indonesia:University of Sumatera Utara.

Grenz *et al.* 2017. Benthic ecology of tropical coastal lagoons: Environmental changes over the last decades in the Te´rminos Lagoon, Mexico. *CR Geoscience* 349:319–329.

Hamli H *et al.* 2012. Taxonomic study of edible bivalva from selected division of Serawak, Malaysia. *Int J Zool Res* 8:52-58

Hartoni, Agussalim A. 2013. Komposisi dan kelimpahan moluska (Gastropoda dan Bivalvia) di ekosistem mangrove muara sungai Musi Kabupaten Banyuasin Provinsi Sumatera Selatan. *Maspari Journal* 5:6-15.

Hummel H *et al.* 2016. Geographic patterns of biodiversity in European coastal marine benthos. *Journal of the Marine Biological Association of the United Kingdom* 97:507-523.

Khan BM, Liu Y. 2019. Marine mollusks: food with benefits. *Comprehensive Reviews in Food Science and Food Safety* 18:548-564.

Krebs CJ. 2014. *Ecological Methodology 3rd. University of British Columbia*. New York: Harper Collins Publisher.

Kuk-Dzul JG *et al.* 2012. Benthic infauna variability in relation to environmental factors and organic pollutants in tropical coastal lagoons from the northern Yucatan Peninsula. *Marine Pollution Bulletin* 64:2725–2733.

Lah RA *et al.* 2017. Investigation of nutritional properties of three species of marine turban snails for human consumption. *Food Science and Nutrition* 5:14-30.

Leidonald R *et al.* 2019. Biodiversity flora and fauna in tropical tidal lake. *In: IOP Conf Ser: Earth Environ Sci*. Medan: IOP Publishing. pp. 1-7.

Morelos-Villegas A *et al.* 2018. Spatial heterogeneity and seasonal structure of physical factors and benthic species in a tropical coastal lagoon, Celestun, Yucatan Peninsula. *Regional Studies in Marine Science* 22:136-146.

Muhtadi A *et al.* 2016. Status Limnologis Danau Siombak, Medan, Sumatra Utara (Limnological Status of Lake Siombak, Medan, North Sumatra). *Oseanologi dan Limnologi Di Indonesia* 1:39-55.

Muhtadi A *et al.* 2017. Morphometry dynamical of siombak lake, Medan Indonesia. *Omni akuatika* 13:48-56.

Muhtadi A *et al.* 2020a. Hydrodynamics of tropical tidal lake waters, Siombak Lake Medan Indonesia. *AACL Bioflux* 13:2014-2031.

Muhtadi A *et al.* 2020b. Spatial Distribution of Mangroves in Tidal Lake Ecosystem. *In: IOP Conf Ser: Earth Environ Sci*. Medan: IOP Publishing. pp. 1-7.

Odum EP, Barrett GW. 2005. *Fundamental of Ecology 5th ed*. Belmont: Brooks/Cole Publishing Co.

Padmavathy A, Anbarashan M. 2013. Biodiversity of coastal Lagoon in Nallavadu village, Puducherry, India. *Int J Biodivers Conserv* 5:33-38.

Pérez-Ruzafa A *et al.* 2019. Connectivity between coastal lagoons and sea: asymmetrical effects on assemblages' and population's structure. *Estuarine, Coastal and Shelf Science* 216:171-186.

Purwaningsih S. 2012. Aktivitas antioksidan dan komposisi kimia keong matah merah (*Cerithidea obtusa*). *Jurnal Ilmu Kelautan* 17:39-48.

Rasyid A, Dody S. 2018. Evaluation of the nutritional value and heavy metal content of the dried marine gastropod *Laevistrombus turturella. AACL Bioflux* 11:1799-1806.

Reis-Filho JA *et al.* 2011. Moon and tide effects on fish capture in a tropical tidal flat. *Journal of the Marine Biological Association of the United Kingdom* 91:735–743.

Rimadiyani W *et al.* 2019. Macrozoobenthos community structure in the Western Segara Anakan Lagoon, Central Java, Indonesia. *Biodiversitas*, 20:588-1596.

Riniatsih I, Kushartono EW. 2009. Substrat dasar dan parameter oseanografi sebagai penentu keberadaan gastropoda dan bivalvia di Pantai Sluke Kabupaten Rembang. *Jurnal Ilmu Kelautan* 14:50-59.

Santoso MR *et al.* 2016. Dekomposisi serasah daun *Rhizophora apiculata* dan kontribusi terhadap unsur hara di perairan Pulau Sembilan Kecamatan Pangkalan Susu Kabupaten Langkat. *Jurnal Aquacoastmarine* 4:29-38.

Shannon CE, Wiener W. 1964. *The Mathematical Theory of Communication*. Urbana: University of Illinois Press.

Suwignyo S *et al.* 2005. *Avertebrata Air: jilid 2. Penebar Swadaya.* Jakarta: Penebar Swadaya.